

Why Image processing?

- Improve pictorial informations for human interpretation
- Processing image for
 - Storage
 - Transmission
 - Representation for autonomous machine

Lecture, Slided. 01

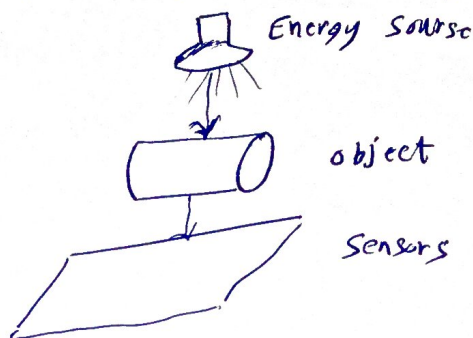
1

- High Level

* output is an interpretation of the image

Ex: interpreting characters in the image

How Image is generated? (Image Source)



object can reflect energy or it can pass through the object then captured by the sensor to generate the image

Image Processing

- input: image - output: image (improved)
- Computer Vision - input: image - output: interpretation for image objects

Digital Image:

- Matrix of pixels $f(x, y)$ where f is the intensity of the pixel

Sources of Images:

- Electromagnetic waves
- Sound waves
- Electronic microscope
- Computer Graphic

plus

Electromagnetic waves

- Stream of massless particles called photons that move with speed of light and have a certain amount of Energy.

- * Gamma-Rays
- * Ultra Violet
- * Infra red
- * Radio wave
- * X-Rays
- * Visible
- * microwaves

Image Processing and other Areas

- Low Level
 - * output is improved image
 - Ex: reduce noise, improve contrast
- Mid Level
 - * output is extracting features from the image
 - Ex: extract characters from image

Applications

Gamma ray

- bone Scane
- PET positron Emission Tomography
- radiations from reactor valve

X-Ray

- CAT Computerize Axial Tomography To form (3D image)
- Checking Circuit board for missing parts
- Aortic angiogram (image of blood vessels using catheter) تصوير الأوعية الدموية

Ultra-Violet

- detect sick Corn

Visible

- Light microscope

Visible / Infrared

- remote sensing
- Weather Forecasting and observation
- detect bubbles in plastic
- detect un-filled bottle in production line
- circuit board checking for missing parts

Micro Waves

- radar

Radio waves

- MRI Magnetic resonance Imaging

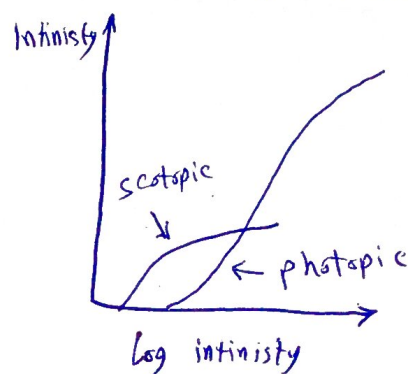
Sound waves

- geological exploration
 - * using Plate plate of steel
 - * making it vibrate using sound waves
 - * sensing the reflecting sound
 - * forming image based on distance and speed of sound and strength
- Sonar
 - * using probe consisting of source and sensors for ultrasound wave

2

Brightness Adaptation

- The range of intensity that human can sense is varying from the Scotopic threshold and the GLare Limit
- The objective brightness is a Log. function of intensity
- Scotopic vision: Low intensity, no-colors
- photopic vision: High intensity, colored

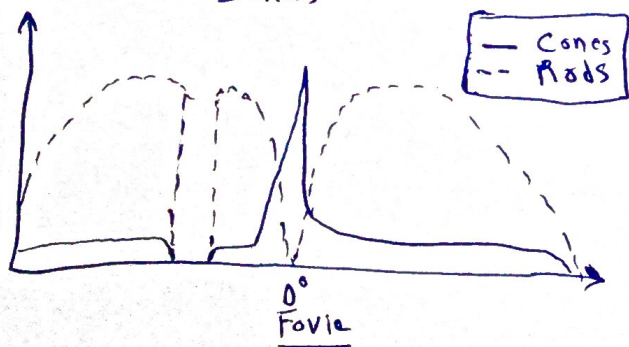


Slide 23,30 → check

Lecture.Slides -02

Human - visual - System - Sensors

- Retina: Contain two types of sensors
 - * Cones: Color sensor
 - * Rods: Low ~~intensity~~ Illumination Sensors



Focal Length

- Vary by changing Lens shape
- 141 mm for near object $\leq 3m$
- 17 mm for far object $> 3m$

Brightness discrimination

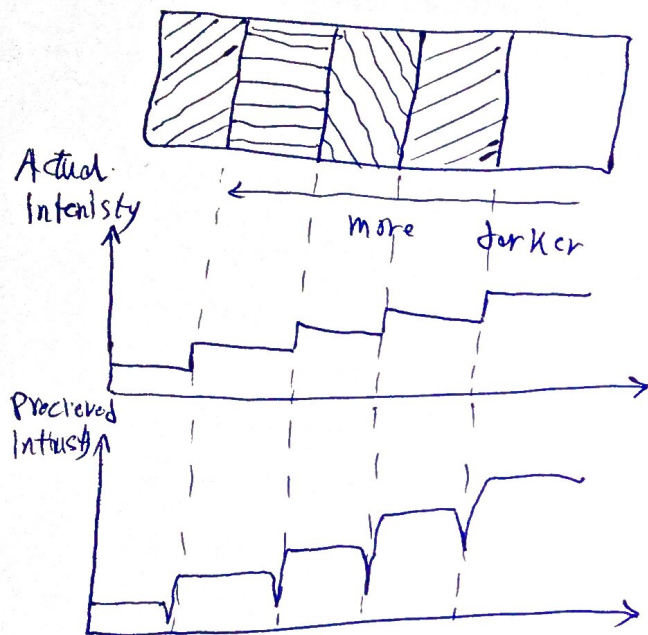
- represent the ability of human to note the change in intensity
- Varying from person to other
- measured with Weber ratio: the ratio between ΔI_c (the change in the intensity that can be detected) and I (the intensity of the background)

$$\text{Weber ratio} = \frac{\Delta I_c}{I}$$

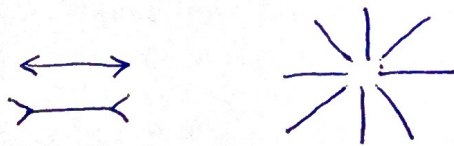
- Good discrimination mean small Weber ratio
- bad discrimination mean large Weber ratio

Brightness is not a simple function of the intensity:

- The human visual system tends to undershoot or overshoot at the boundary of mesh bars



- When The background of an object becomes more lighter the object looks more darker
- Optical illusion



Electromagnetic waves

- Energy $E = h \nu$
 $h \rightarrow$ Planck constant
 $\nu \rightarrow$ frequency
- Wave Length $\lambda = \frac{c}{\nu}$
 $c \rightarrow$ Light speed $2.998 \times 10^8 \text{ m/s}$

- To see an object the wave length of EM wave used as energy source must be the same or smaller than the object

Light Characteristics

- Mono chromatic (achromatic) not colored
 - * Intensity
 - * Gray Levels
- Chromatic (colored) Light
 - * Radiance
 - * Luminance
 - * Brightness

Radiance: The amount of energy flow from light source (watt)

Luminance: The amount of energy perceived by observer from light source (Lumen)/(lm)

Type of sensors

- 1- Single sensor
 - resolution depends on the mechanical motion in the booth ~~directions~~ ^{dimension}
- 2- Strip sensor
 - resolution depends on the no. of sensors in one dimension and the mechanical ~~motion~~ ^{motion} in the other
- 3- Ring sensor
 - used to take 3D image like in CAT
- 4- Array sensor
 - no mechanical motion
 - depend on no. of sensors in 'booth dimension'

Image Model

$$0 < f(x, y) < \infty$$

$$f(x, y) = i(x, y) \cdot r(x, y)$$

$$0 < r(x, y) < 1$$

$$0 < i(x, y) < \infty$$

Acqually

$$L_{\min} < f(x, y) < L_{\max}$$

$i(x, y)$ illumination

- The amount of energy fall on the surface of imaged object (lm/m^2)

$r(x, y)$ reflectance

- The ability of object to reflect the fallen energy

Lecture Slides . 03

Sampling and Quantization

- * Sampling: Converting spacial from continuous to discrete
 - Depend on the type of sensor

- * quantization: Converting intensity from continuous to discrete

- Depend on the number of bits used to represent each pixel

$$*(L = 2^k) \rightarrow \text{No. of possible gray levels}$$

$$*(M \times N) \rightarrow \text{No. of pixels used to represent the image}$$

$$*(k) \rightarrow \text{No. of bits used to represent pixel}$$

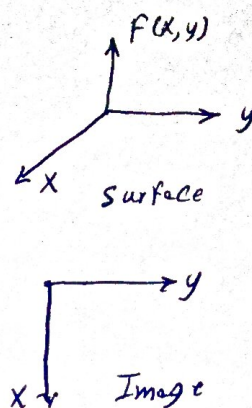
$$* \text{Dynamic Range} = \frac{\text{Max intensity Level}}{\text{Min intensity Level}}$$

$$* \text{Contrast} = \text{Max intensity Level} - \text{Min intensity Level}$$

$$* \text{Image Size} = M \times N \times k \text{ (bit)}$$

Image Representation

- Surface
- Image (for human)
- Array ($M \times N$) ~~for algorithms~~ for Algorithms



Notes

- Max intensity Level is controlled by Saturation
- Min intensity Level is controlled by the noise

Resolution

~~Spatial~~

* Spatial resolution

- No. of pixels per unit distance
- Affected by the distance between the pixels
- Unit to measure it is DPI \rightarrow Dot Per Inch

* Intensity Level resolution

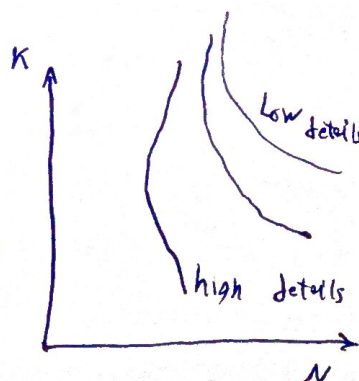
- No. of possible intensity levels (L)
- No. of bits used to represent the intensity of each pixel (k)

Isoreference Curves

- each ~~curve~~ curve represent equal quality images
- $k \rightarrow$ No. of bits (intensity)
- $N \rightarrow$ No. of pixels (spatial)
- When details increase we need Low intensity resolution

- When details decrease we need High intensity resolution

- The curve tends to be vertical in image with high details because we
 - Need Low intensity Levels to represent the image in good quality



Interpolation

5

* The operation of filling holes in the image

* holes: pixels with unknown intensity level after ~~performing~~ performing some operations on the image
Ex: Stretching the image

Types of Interpolation

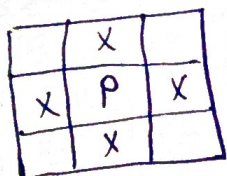
- * Nearest Neighbor
 - Low quality
- * Bilinear
 - Good quality
 - Use 4 nearest neighbor
 - Use this equation
$$F(x, y) = ax + by + cxy + d$$
- * Bicubic
 - High quality
 - Use 16 nearest neighbor

Neighbors of Pixels

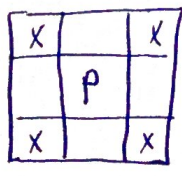
$N_4(P)$ → Set of horizontal and vertical neighbors

$N_D(P)$ → Set of Diagonal neighbors

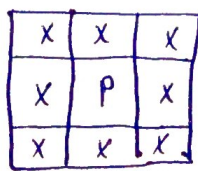
$N_8(P)$ → $N_4(P) \cup N_D(P)$



$N_4(P)$



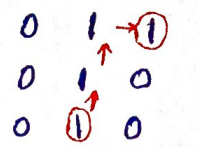
$N_D(P)$



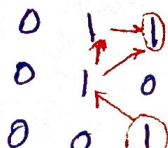
$N_8(P)$

Adjacent: The set of neighbors that are part the Adjacency set V

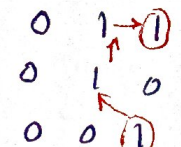
$$V = \{1\}$$



4-adjacency



8-adjacency



m-adjacency

* 4-adjacency:

The pixels P and q are 4-adjacent when q belongs to V and q belongs to $N_4(P)$

* 8-adjacency:

The pixels P and q are 8-adjacent when q belongs to V and q belongs to $N_8(P)$

* m-adjacency (mixed)

The pixels P and q are m-adjacent when q belongs to V and
1- q belongs to $N_4(P)$, or
2- q belongs to $N_8(P)$ and the intersection of $N_4(P)$ and $N_4(q)$ is not part of V
 $N_4(q) \cap N_4(P) \not\subset V$

Distance Measure

~~* Manhattan~~

* Euclidean distance

- The distance of straight line between the two pixels

$$d_e = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

$\sqrt{8}$	$\sqrt{5}$	2	$\sqrt{5}$	$\sqrt{8}$
$\sqrt{5}$	$\sqrt{2}$	1	$\sqrt{2}$	$\sqrt{5}$
2	1	0	1	2
$\sqrt{5}$	$\sqrt{2}$	1	$\sqrt{2}$	$\sqrt{5}$
$\sqrt{8}$	$\sqrt{5}$	2	$\sqrt{5}$	$\sqrt{8}$

* Manhattan Distance (city block)

- The distance between N_4 is 1
- The distance between N_8 is 2
- Form diamond ~~form~~ shape
- $d_m = |x_1 - x_2| + |y_1 - y_2|$

2
2 1 2
2 1 0 1 2
2 1 2
2

* Chessboard distance

- The distance between N_8 is 1
- Form square shape

2 2 2 2 2
2 1 1 1 2
2 1 0 1 2
2 1 1 1 2
2 2 2 2 2

$$d_c = \max(|x_1 - x_2|, |y_1 - y_2|)$$

Lecture slides . 04

Array operations

- Each pixel operates with its corresponding pixel
- Default

Matrix operations

- Standard matrix operations
- If stated

Linear operations

- operations are linear if they are homogeneity and additivity

$$\rightarrow H[a F(x, y)] = a H[F(x, y)] \text{ homogeneity}$$

$$\rightarrow H[a_1 F_1(x, y) + a_2 F_2(x, y)] = a_1 H[F_1(x, y)] + a_2 H[F_2(x, y)] \text{ additivity}$$

6

~~Addition~~

- Sum of all pixels is Linear
- min is not Linear
- max is not Linear

Application on Arithmetic

Addition

- * Reduce noise using the Average of many noisy images taken by the same sensor for the same scene

Subtraction

* Mask mode Radiography

- 1- We take an x-ray image for region of patient's body. $F(x, y)$
- 2- We take another image after injecting contrast medium in patient's blood stream. $h(x, y)$
- 3- We can see the flow of medium using subtraction. $h(x, y) - F(x, y)$

- * See difference between two images

Multiplication

* Shading Correction

- We take an image using the same sensor for constant intensity object. $h(x, y)$
- We can correct shading by dividing the target image by $h(x, y)$

* Masking

- We multiply a binary image with our target image to obtain the region of ~~interest~~ interest.

Correcting Range of the result

7

- After performing an operation the resulting intensity values can be negative or more than the max-value.

- Create the min is zero

$$F_m(x,y) = F(x,y) - \text{Min}[F(x,y)]$$

- Scaling image intensity

$$F_s(x,y) = L \left(\frac{F_m(x,y)}{\text{Max}[F_m(x,y)]} \right)$$

Where L is No. of gray Levels

Sets operations → slides 12: 17

Lecture. Slides. 05